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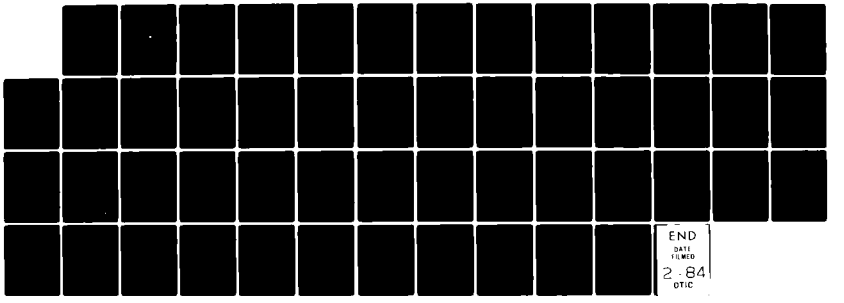

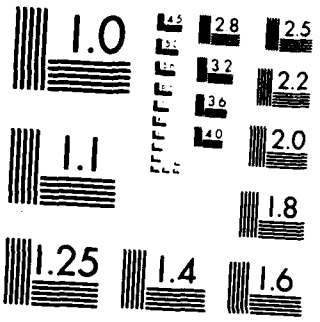

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NAVAL POSTGRADUATE SCHOOL

Monterey, California

POSITION DETERMINATION WITH LORAN-C
TRIPLETS USING THE HEWLETT-PACKARD HP-75C,
THE SHARP PC-1500 (TRS-80 PC-2) OR
THE RADIO SHACK TRS-80 MODEL 100
PORTABLE COMPUTERS

by

Rex H. Shudde

September 1983

Prepared for:
Chief of Naval Research
Arlington, VA 22217

NAVAL POSTGRADUATE SCHOOL
Monterey, California

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This report contains user instructions and program listings for a Loran-C position determination algorithm for use on an Hewlett-Packard HP-75C, a Sharp PC-1500 (Radio Shack TRS-80 PC-2) and a Radio Shack Model 100 portable computers.

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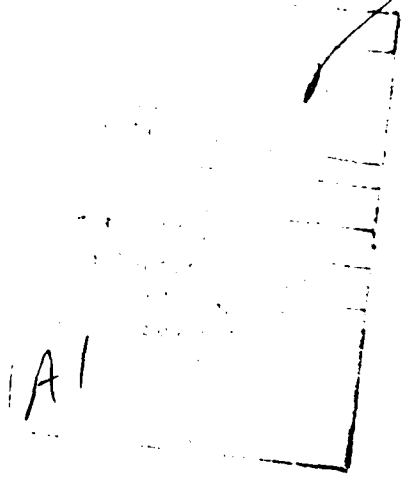

September 1983

The programs in this report are for use within the Navy, and they are presented without representation or warranty of any kind.

CONTENTS

ABSTRACT

This report contains user instructions and program listings for a Loran-C position determination algorithm for use on an Hewlett-Packard HP-75C, a Sharp PC-1500 (Radio Shack TRS-80 PC-2) and a Radio Shack Model 100 portable computers.

I. INTRODUCTION

This report contains a Loran-C position determination program for each of the following portable computers: the Hewlett-Packard HP-75C, the Sharp PC-1500 (Radio Shack TRS-80 PC-2) and the Radio Shack) TRS-80 Model 100. These programs are part of a set that has been developed for a portable computer evaluation.

The Loran system is a radio aid to navigation which utilizes the principle of hyperbolic fixing. The locus of points for which the difference in arrival time of synchronized signals from a pair of transmitters is constant determines a hyperbolic line of positions. The intersection of two hyperbolic lines of position from two pairs of stations determines a hyperbolic fix. That two pairs of stations are required for a fix does not necessarily mean that there are four separate stations, for one station of one pair may be colocated with one station of the other pair forming a Loran triplet. Triplets may be joined "end-to-end" by station colocation to form a Loran chain. Loran chains are common on both the East and West coasts of the North American continent.

The present day Loran-C operates at 100-kHz and is in use in the Atlantic, Pacific and Mediterranean areas. The computational programs described herein can be used for position determination with Loran-C triplets. Further information on the history, development and operation of the Loran systems may be found in References 1 and 2. Details of the fixing algorithm can be found in Reference 3.

In the programs presented here, there are ten user options. The computer display abbreviations for the option names and their definitions are listed below.

1. LORAN FIX. This fixing routine is the main program for calculating a LORAN-C fix from indicated time delays (ITDs).
2. ALTERNATE SOLN. The alternate solution routine will allow the second LORAN-C fix solution to be computed. This routine toggles an alternate solution flag so that on subsequent fixes Option 1 will calculate the alternate solution.
3. INPUT DEST LAT/LONG. This option is used to store the latitude and longitude of a destination.
4. HEAD & DIST TO DEST. This option is used to compute the heading and distance from the currect fix to the destination stored by Option 3.
5. PREDICT ITDs. This option may be used to predict the station ITDs that will be received at a given latitude and longitude.
6. TWO POINT HEAD & DIST. This option is similiar to Option 4 except that it may be used to compute the heading and distance from any origin to any destination.
7. CALIBRATE. Given the latitude and longitude of a benchmark position and the indicated time delays from a LORAN-C triplet received at the benchmark position, the stored station data are modified so that the fix routine (or alternate solution routine) will compute the known position from the same time delays.

8. NEW STA. IDs. This option is used to load the two station pairs being received by requesting the group repetition interval (GRI) identifier.
9. ASF Corrections. When a portion of the propagation path lies over land, the additional secondary factor (ASF) should be included in the observed time delay if precision navigation is required. This option allows the user to input the ASF correction [Ref. 4, 5].

A. STOP. This option will exit from the LORAN-C routine.

An additional HELP option (H) is available in the Hewlett-Packard HP-75C and Sharp PC-1500 (TRS-80 PC-2) computers. This option will review the ten options in the display. The Radio Shack TRS-80 Model 100 does not have this option because all ten options can be displayed simultaneously.

II. THE HEWLETT-PACKARD HP-75C.

HP-75C USER INSTRUCTIONS.

The options are labeled 1 through 9, A or H. The H (Help) option will review options 1 - 9 & A. Option 6 (TWO POINT HEAD & DIST) is a stand-alone option which may be used by itself. For LORAN fixing, Option 8 must be selected first to load the station GRI's. If Option 8 is not used, then any option requiring the GRI's will automatically enter Option 8 first. Option 1 (LORAN FIX) must be selected at least once before Option 2 (ALTERNATE SOLN) can be selected. Once the GRI's are loaded, any of the remaining options may be used at any time. When first run, the ASF Correction Factors are set to zero; if they are subsequently entered as non-zero values they will remain set until either changed manually, by selection of Option 9, or until the program is RUN once more. In all cases, South latitudes and East longitudes must be negative for input and will be labeled by a minus sign '-' on output. For ease of reference the options are listed by number rather than by sequence of selection.

INSTRUCTION	DISPLAY	INPUT
Run Program		Run "LORAN"
	NEXT OPTION (Help)?	
1. LORAN FIX		1
ITD for 1st GRI	ITD FOR gri 1?	1st ITD [RTN]
ITD for 2nd GRI	ITD FOR gri 2?	2nd ITD [RTN]
Lat of fix	LAT = dd°mm'ss"	[RTN]
Long of fix	LONG = ddd°mm'ss"	[RTN]
	NEXT OPTION (Help)?	
2. ALTERNATE SOLN		2
Lat of fix	LAT = dd°mm'ss"	[RTN]
Long of fix	LONG = ddd°mm'ss"	[RTN]
	NEXT OPTION (Help)?	
3. INPUT DEST LAT/LONG		3
	DEST LAT dd.mmss?	Lat of dest. [RTN]
	DEST LONG ddd.mmss?	Long of dest. [RTN]
	NEXT OPTION (Help)?	
4. HEAD & DIST TO DEST		4
Heading to dest.	HEADING = dd°mm'ss"	[RTN]
Dist. to dest.	DISTANCE = mmm.ff n.mi.	[RTN]
	NEXT OPTION (Help)?	

INSTRUCTION	DISPLAY	INPUT
5. PREDICT ITDs		5
	LAT dd.mmss?	Lat [RTN]
	LONG ddd.mmss?	Long [RTN]
1st ITD	ITD FOR gri 1 = xxxxx.xx µs	[RTN]
2nd ITD	ITD FOR gri 2 = xxxxx.xx µs	[RTN]
	New Lat/Lon or Return to menu	N repeats Option 5 R goes to next line
	NEXT OPTION (Help)?	
6. TWO POINT HEAD & DIST		6
	ORIGIN LAT dd.mmss?	Lat of origin [RTN]
	ORIGIN LONG ddd.mmss?	Long of origin [RTN]
	DEST LAT dd.mmss?	Lat of dest. [RTN]
	DEST LONG ddd.mmss?	Long of dest. [RTN]
Heading to dest.	HEADING = dd°mm'ss"	[RTN]
Dist. to dest.	DISTANCE = mmm.ff n.mi.	[RTN]
	NEXT OPTION (Help)?	
7. CALIBRATE		7
	LAT dd.mmss?	Lat of fix [RTN]
	LONG ddd.mmss?	Long of fix [RTN]
	ITD FOR gri 1?	1st ITD [RTN]
	ITD FOR gri 2?	2nd ITD [RTN]
	NEXT OPTION (Help)?	
8. NEW STA. IDs		8
	1st GRI?	Sta. ID [RTN]
	2nd GRI?	Sta. ID [RTN]
	NEXT OPTION (Help)?	
9. ASF Corrections		9
	ASF FOR gri 1?	1st ASF [RTN]
	ASF FOR gri 2?	2nd ASF [RTN]
	NEXT OPTION (Help)?	
A. STOP		A
	>	

HP-75C SAMPLE PROBLEM 1

You are sailing off of the coast of California. Your destination is Moss Landing at about 36°48'N and 121°47'W. Your present ITD from station pair GRI 9940W is 16019 and your ITD from station pair GRI 9940Y is 42585. What is your current position and what is the heading and distance from your current position to Moss Landing? We assume that the GRI's 9940W and 9940Y have not yet been loaded.

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?	3	Input destination.
DEST LAT dd.mmss?	36.48 [RTN]	36°48'
DEST LONG ddd.mmss?	121.47 [RTN]	121°47'
NEXT OPTION (Help)?	8	Input station ID's.
1st GRI?	9940W [RTN]	
2nd GRI?	9940Y [RTN]	
NEXT OPTION (Help)?	1	Compute a fix.
ITD FOR 9940W?	16019	
ITD FOR 9940Y?	42585	
LAT = 39°14'19"	[RTN]	Latitude of fix.
LONG = 115°50'52"	[RTN]	Longitude of fix.

This fix is in Nevada. There are always two solutions to the LORAN equations. The navigator must select the correct one.

NEXT OPTION (Help)?	2	Select alternate soln.
LAT = 35°00'01"	[RTN]	Latitude of fix.
LONG = 125°00'09"	[RTN]	Longitude of fix.

This fix is in the Pacific. The navigator knows it is the correct fix because of his estimate of where he should be.

NEXT OPTION (Help)?	4	Find heading & distance to destination.
HEADING = 54°34'11"	[RTN]	Heading to Moss Landing.
DISTANCE = 190.38 n.mi.	[RTN]	Distance to Moss Landing.
NEXT OPTION (Help)?		Repeat with new option or press A to quit.

HP-75C SAMPLE PROBLEM 2

How far, and in what direction, is Corvallis, Oregon (44°34'N, 123°16'W) from Cupertino, California (37°19'N, 122°02'W)?

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?	6	Two point distance and heading.
ORIGIN LAT dd.mmss?	37.19 [RTN]	37°19'
ORIGIN LONG ddd.mmss?	122.02 [RTN]	122°02'
DEST LAT dd.mmss?	44.34 [RTN]	44°34'
DEST LONG ddd.mmss?	123.16 [RTN]	123°16'
HEADING = 353 02'59"	[RTN]	
DISTANCE = 438.32 n.mi.	[RTN]	
NEXT OPTION (Help)?		Repeat with new option or press A to quit.

HP-75C SAMPLE PROBLEM 3

Suppose that you want to know what ITD's you would expect to receive at 35° North, 125° West and at 36°27' North, 126°54' West from 9940W and 9940Y. To determine these ITD's, proceed as follows (assume that the GRI's have been loaded as in Sample Problem 1):

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?	5	Predict ITD's.
LAT dd.mmss?	35 [RTN]	35°
LONG ddd.mmss?	125 [RTN]	125°
ITD FOR 9940W = 16019.35 µs	[RTN]	
ITD FOR 9940Y = 42584.71 µs	[RTN]	
New Lat/Lon or Return to menu?	N	
LAT dd.mmss?	36.27 [RTN]	36°27'
LONG ddd.mmss?	126.54 [RTN]	126°54'
ITD FOR 9940W = 15572.32 µs	[RTN]	
ITD FOR 9940Y = 43006.15 µs	[RTN]	
New Lat/Lon or Return to menu?	R	
NEXT OPTION (Help)?		Repeat with new option or press A to quit.

HP-75C SAMPLE PROBLEM 4

Suppose you are receiving an ITD of 16308 from 9940W and 42800 from 9940Y. These ITD's would tell you that your location is 36°47'55"N and 121°47'11"W. However, you know that your position is benchmarked to be at 36°47'36"N and 121°46'58"W, and you wish to calibrate your HP-75C so that the ITD's of 16308 and 42800 will give you the latter fix instead of the former. Proceed as follows (assume the GRI's have been loaded as in Sample Problem 1):

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?	7	Calibrate.
LAT dd.mmss?	36.4736 [RTN]	36°47'36"
LONG ddd.mmss?	121.4658 [RTN]	121°45'58"
ITD FOR 9940W?	16308 [RTN]	
ITD FOR 9940Y?	42800 [RTN]	

The station baselines have now been modified to achieve calibration. Now, reenter 16038 and 42800 into the fixing routine to test the calibration. Calibration does not modify the permanent station data stored in the HP-75C. The calibration remains effective until the GRI's are reloaded by Option 8. NOTE: The affect of calibration on the accuracy of fixes far removed from the benchmark has not been studied. The user should use the calibration option with caution.

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?	1	Compute a fix.
ITD FOR 9940W?	16308 [RTN]	
ITD FOR 9940Y?	42800 [RTN]	
LAT = 36°47'35"	[RTN]	Lat of fix.
LONG = 121°46'59"	[RTN]	Long of fix.

The small discrepancy between this fix and the benchmark is due to assumptions in the fixing algorithm. If higher precision is required, the ASF Correction factor may be used (see Sample Problem 5). Note that you may need to use the Alternate Solution Option 2 if the fix obtained above is near 38°52'57"N and 116°51'11'W.

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?		Repeat with new option or press A to quit.

HP-75C SAMPLE PROBLEM 5

Suppose you are receiving an ITD of 12153.31 microseconds from 9960W and 44451.83 microseconds from 9960Y. These ITD's would tell you that your location is 44°15'05"N and 67°25'23"W. Entering the ASF Correction Tables [Ref. 5,6] with these readings, the ASF Correction for GRI 9960W at 44°15'N and 67°25'W is 1.5 microseconds. Similiarly, the ASF Correction for GRI 9960Y at these coordinates is 2.7 microseconds. Enter these corrections into your HP-75C and recompute your position. (Load the GRI's 9960W and 9960Y using Option 8).

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?	9	ASF Correction.
ASF FOR 9960W?	1.5 [RTN]	
ASF FOR 9960Y?	2.7 [RTN]	
NEXT OPTION (Help)?	1	Compute a fix.
ITD FOR 9960W?	12153.31 [RTN]	
ITD FOR 9940Y?	44451.83 [RTN]	
LAT = 44°15'26"	[RTN]	
LONG = 67°26'26"	[RTN]	
NEXT OPTION (Help)?		Repeat with new option or press A to quit.

These ASF Corrections have been entered into the computer. The range of their validity must be checked with the ASF Correction tables and reentered if they change. NOTE: If you are using the ASF Correction Tables and if you wish to calibrate to a benchmark position, you should first enter the ASF Corrections for your benchmark and then use the calibration Option 7 (see Sample Problem 4).

HP-75C PROGRAM LISTING

```
10 REM LORAN-C ROUTINE.
rev 07-08-83. 1330 HOURS
.
20 N9=15 @ REM N9=# OF M
ASTER STATIONS
30 OPTION ANGLE RADIANS
@ OPTION BASE 1
40 DEF FNR(X,M) = INT(M*
X+.5)/M
50 C0=1/298.26 @ A0=-1 @
 G1$=""
60 DEF FNP(T) = 129.0439
8/T-.40758+.00064576438*
T
70 DEF FNQ(T) = 2.741297
9/T-.011402+.00032774624
*T
80 DISP @ GOTO 120
90 C$=KEY$ @ IF C$="" TH
EN 90
100 C$=UPRC$(C$) @ FOR C
=1 TO LEN(C0$) @ IF C$=C
0$[C,C] THEN DISP @ RETU
RN
110 NEXT C @ GOTO 90
120 DISP "NEXT OPTION ("
;CHR$(200);"elp)?" @ C0$
="123456789AH" @ GOSUB 9
0
130 ON C GOSUB 910,950,1
010,1040,1090,990,1200,1
90,1350,530,140 @ GOTO 1
20
140 DISP "1 - LORAN FIX"
 @ DISP "2 - ALTERNATE S
OLN" @ DISP "3 - INPUT D
EST LAT/LONG"
150 DISP "4 - HEAD & DIS
T TO DEST" @ DISP "5 - P
REDICT ITDs"
160 DISP "6 - TWO POINT
HEAD & DIST" @ DISP "7 -
 CALIBRATE"
170 DISP "8 - NEW STA. I
Ds" @ DISP "9 - ASF Corr
ections" @ DISP "A - STO
P"
180 RETURN
182 REM OPT 8
185 IF G1$()"" THEN RETU
RN
190 F0=1 @ N=1 @ INPUT "
1st GRI? ",I$
200 GOSUB 380 @ GOSUB 39
0 @ IF F0=2 THEN 190
210 F0=1 @ N=2 @ INPUT "
2nd GRI? ", I$ @ GOSUB 3
80
220 IF A$=I9$ THEN GOSUB
 470 ELSE 240
230 IF F0=1 THEN 250
240 GOSUB 390 @ IF F0=2
THEN 210
250 F1=1 @ F2=1 @ IF G1$
=G2$ THEN 300
260 IF P(1,1)=P(1,2) AND
 L(1,1)=L(1,2) THEN 310
270 F2=-1 @ IF P(1,1)=P(
2,2) AND L(1,1)=L(2,2) T
HEN 310
280 F1=-1 @ IF P(2,1)=P(
2,2) AND L(2,1)=L(2,2) T
HEN 310
290 F2=1 @ IF P(2,1)=P(1
,2) AND L(2,1)=L(1,2) TH
EN 310
300 DISP "E. NO TRIPLET
 ",G1$," & ";G2$ @ GOSUB
 1370 @ GOTO 190
310 FOR I=1 TO 2 @ P1=P(
1,I) @ L1=L(1,I) @ P2=P(
2,I) @ L2=L(2,I)
320 DISP @ GOSUB 330 @ N
EXT I @ G(1)=0 @ G(2)=0
@ RETURN
330 GOSUB 650 @ B(I)=S0
@ Z(1,I)=Z1 @ Z(2,I)=Z2
340 T=21282.3593*S0
350 IF T)=537 THEN P=FNP
(T)
360 IF T<537 THEN P=FNQ(
T)
370 T(I)=T+P @ RETURN
```

```
380 L=LEN(I$) @ A$=I$[1,
L-1] @ B$=I$[L,L] @ B=NU
M(B$) @ B$=CHR$(B-32*(B)
90)) @ RETURN
390 N8=1 @ RESTORE
400 READ I9$,N0,P0,L0 @
W$=""
410 FOR I=1 TO N0 @ READ
 W0$,D9(I),P1(I),L1(I) @
 W$=W$&W0$ @ NEXT I
420 IF I9$@A$ THEN 450
430 GOSUB 470 @ IF F0=2
THEN 460
440 RETURN
450 N8=N8+1 @ IF N8<=N9
THEN 400
460 DISP I$;" IS NOT CAT
ALOGED" @ F0=2 @ GOSUB 1
370 @ RETURN
470 FOR I=1 TO N0 @ IF W
$[I,I]=B$ THEN 490
480 NEXT I @ F0=2 @ RETU
RN
490 IF N=1 THEN G1$=I$
500 IF N=2 THEN G2$=I$
510 D(N)=D9(I) @ P(1,N)=
FNA(RAD(FNH(P0))) @ L(1,
N)=RAD(FNH(L0))
520 P(2,N)=FNA(RAD(FNH(P
1(I)))) @ L(2,N)=RAD(FNH
(L1(I))) @ RETURN
530 DISP @ PUT CHR$(13)
@ END
540 REM DIR SOLN
550 Z8=SIN(Z1) @ Z9=COS(
Z1) @ P8=SIN(P1) @ P9=CO
S(P1) @ M=-Z8*P9 @ C1=C0
*M @ C2=C0*(1-M*M)/4
560 D=(1-C2)*(1-C2-C1*M)
 @ P=C2*(1+C1*M/2)/D @ N
=P9*Z9
570 S1=ANGLE(P8,N) @ D0=
S0/D @ U=2*(S1-D0) @ W=1
-2*P*COS(U) @ V=COS(U+D0
)
580 X=C2*C2*SIN(D0)*COS(
D0*(2*V*V-1)) @ Y=2*P*V*
W*SIN(D0)
590 S2=D0+X-Y @ S8=SIN(S
2) @ S9=COS(S2) @ K=SQR(
M*M+(N*S9-P8*S8)^2)
600 P2=ATN((P8*S9+N*S8)/
K)
610 S3=ANGLE(P9*S9-P8*S8
*Z9,-S8*Z8)
620 H=C1*(1-C2)*S2-C1*C2
*S8*COS(S1+S1-S2) @ L2=L
1+S3-H
630 Z2=ANGLE(-(N*S9-P8*S
8),-M) @ RETURN
640 REM REVERSE SOLN
650 L3=L2-L1 @ P3=(P2-P1
)/2 @ P4=(P1+P2)/2
660 P6=SIN(P3) @ P7=COS(
P3) @ P8=SIN(P4) @ P9=CO
S(P4)
670 H=P7*P7-P8*P8 @ L=P6
*P6+H*SIN(L3/2)^2 @ D0=2
*ASIN(SQR(L))
680 U=2*P8*P8*P7*P7/(1-L
) @ V=2*P6*P6*P9*P9/L @
X=U+V @ Y=U-V @ T=D0/SIN
(D0) @ D=4*T*T
690 E=2*COS(D0) @ A=D*E
@ C=T-(A-E)/2 @ N1=X*(A+
C*X) @ B=D+D @ N2=Y*(B+E
*Y) @ N3=D*X*Y
700 D2=C0*C0*(N1-N2+N3)/
64 @ D1=C0*(T*X-Y)/4 @ S
0=(T-D1+D2)*SIN(D0)
710 M=32*T-(20*T-A)*X-(B
+4)*Y
720 F=Y+Y-E*(4-X) @ G=C0
*(T/2+C0*M/64) @ Q=-F*G*
TAN(L3)/4
730 L4=(L3+Q)/2 @ L8=SIN
(L4) @ L9=COS(L4)
740 T1=ANGLE(P9*L8,P6*L9
) @ T2=ANGLE(P8*L8,-P7*L
9)
```

```
750 T9=PI+PI @ Z1=MOD(T1
+T2,T9) @ Z2=MOD(T1-T2,T
9) @ RETURN
760 REM FIXING ROUTINE
770 A1=F1*SIN(A(1)) @ B1
=COS(A(1))-COS(B(1)) @ C
1=SIN(B(1))
780 A2=F2*SIN(A(2)) @ B2
=COS(A(2))-COS(B(2)) @ C
2=SIN(B(2))
790 E1=Z(1,1) @ IF F1=-1
 THEN E1=Z(2,1)
800 E2=Z(1,2) @ IF F2=-1
 THEN E2=Z(2,2)
810 C=B1*C2*COS(E2)-B2*C
1*COS(E1) @ S=B1*C2*SIN(
E2)-B2*C1*SIN(E1)
820 K=B2*A1-B1*A2 @ R=SQ
R(C*C+S*S) @ G=ANGLE(C,S
)
830 Z=G+A0*ACOS(K/R) @ S
0=ANGLE(C2*COS(Z-E2)+A2.
B2)
840 IF F2=1 THEN P1=P(1.
2) @ L1=L(1,2)
850 IF F2=-1 THEN P1=P(2
,2) @ L1=L(2,2)
860 Z1=Z @ GOSUB 550 @ P
0=P2 @ L0=L2 @ P=ATN(TAN
(P0)/(1-C0))
870 P=DEG(P) @ L=MOD(DEG
(L0),360) @ IF L>180 THE
N L=L-360
880 P$=FND$(P) @ L$=FND$
(L)
890 DISP "LAT = ";P$ @ G
OSUB 1370 @ DISP "LONG =
 ";L$ @ GOSUB 1370 @ RET
URN
900 REM OPT 1 - COMPUTE
FIX
910 GOSUB 185 @ FOR I=1
TO 2 @ G$=G1$ @ IF I=2 T
HEN G$=G2$
920 DISP "ITD FOR ";G$;
@ INPUT "? "; A @ A=A+G(
I)-D(I)-T(I) @ IF ABS(A)
<T(I) THEN 940
930 DISP "E. ITD NOT VAL
ID FOR ";G$ @ GOTO 920
940 A(I)=A/21295.8736 @
NEXT I @ GOSUB 770 @ RET
URN
950 IF A0=1 THEN A0=-1 @
 GOTO 965
960 A0=1
965 IF G1$="" THEN 910
970 GOSUB 770 @ RETURN
980 REM OPT 6
990 INPUT "ORIGIN LAT dd
.mmss? "; P @ INPUT "ORI
GIN LONG ddd.mmss? ";L
1000 P0=FNA(RAD(FNH(P)))
 @ L0=RAD(FNH(L)) @ GOSU
B 1010 @ GOSUB 1040 @ RE
TURN
1010 INPUT "DEST LAT dd.
mmss? "; P @ INPUT "DEST
 LONG ddd.mmss? ";L
1020 P5=FNA(RAD(FNH(P)))
 @ L5=RAD(FNH(L)) @ RETU
RN
1030 REM OPT 4
1040 P1=P0 @ L1=L0 @ P2=
P5 @ L2=L5 @ GOSUB 650
1050 Z=MOD(DEG(Z1),360)
@ Z$=FND$(Z)
1060 DISP "HEADING = ";Z
$ @ GOSUB 1370 @ DISP "D
ISTANCE = ";FNR(3443.917
*S0,100);" n.mi."
1070 GOSUB 1370 @ RETURN
1080 REM OPT 5
1090 GOSUB 185 @ GOSUB 1
170 @ FOR K=1 TO 2 @ I9=
T(K)+D(K)
1100 P2=P(2,K) @ L2=L(2,
K) @ GOSUB 650 @ I=3 @ G
OSUB 340 @ I9=I9+T(3)
```

```
1110 P2=P(1,K) @ L2=L(1,
K) @ GOSUB 650 @ I=3 @ G
OSUB 340 @ I9=I9-T(3)
1120 I$=G1$ @ IF K=2 THE
N I$=G2$
1130 DISP "ITD FOR ";I$;
" =";FNR(I9,100);CHR$(12
);"s" @ GOSUB 1370 @ NEX
T K
1140 DISP CHR$(206);"ev
Lat/Lon or ";CHR$(210);"
eturn to menu?" @ C0$="N
P" @ GOSUB 90
1150 IF C=1 THEN 1090
1160 RETURN
1170 INPUT "LAT dd.mmss?
"; P1 @ INPUT "LONG ddd
.mmss? ";L1
1180 P1=FNA(RAD(FNH(P1))
) @ L1=RAD(FNH(L1)) @ RE
TURN
1190 REM OPT 7
1200 GOSUB 185 @ GOSUB 1
170 @ FOR K=1 TO 2 @ I$=
G1$ @ IF K=2 THEN I$=G2$
1210 DISP "ITD FOR ";I$;
 @ INPUT "? "; I9 @ I9=I
9-D(K)
1220 P2=P(2,K) @ L2=L(2,
K) @ GOSUB 650 @ I=3 @ G
OSUB 340 @ I9=I9-T(3)
1230 P2=P(1,K) @ L2=L(1,
K) @ GOSUB 650 @ I=3 @ G
OSUB 340 @ T(K)=I9+T(3)+
G(K)
1240 NEXT K @ RETURN
1250 DEF FNH(X)
1260 S=SGN(X) @ X=ABS(X)
 @ H=INT(X) @ V=FP(X)*10
0 @ FNH=S*((100*FP(V)/60
+INT(V))/60+H)
1270 END DEF
1280 DEF FNA(X) = ATN((1
-C0)*TAN(X))
1290 DEF FND$(X)
1300 C$=" " @ IF X<0 THE
N C$="-"
1310 X=ABS(X)+1/7200 @ X
0=INT(X) @ C$=C$&STR$(X0
)&CHR$(1)
1320 X=60*(X-X0) @ X0=IN
T(X) @ X$=STR$(100+X0) @
 C$=C$&X$[2,3]&"'"
1330 X=60*(X-X0) @ X0=IN
T(X) @ X$=STR$(100+X0) @
 FND$=C$&X$[2,3]&CHR$(34
)
1340 END DEF
1350 GOSUB 185 @ DISP "A
SF FOR ";G1$; @ INPUT "?
 ";G(1)
1360 DISP "ASF FOR ";G2$
; @ INPUT "? "; G(2) @ R
ETURN
1370 C$=KEY$ @ IF C$=""
THEN 1370
1380 DISP @ RETURN
5000 DATA 4990,2,16.4443
95,169.38312,"X",11000,2
0.144916,155.53097
5010 DATA "Y",29000,28.2
34177,178.17382
5020 DATA 5930,2,46.4827
199,67.5537713,"X",11000
,41.151193,69.583909
5030 DATA "Y",25000,46.4
63218,53.102816
5040 DATA 5970,3,36.1105
797,-129.2027279,"W",110
00,42.4437104,-143.43092
45
5050 DATA "X",31000,35.0
223871,-126.3226741,"Z",
42000,26.3624975,-128.08
56445
5060 DATA 5990,3,51.5758
78,122.228224,"X",11000,
55.2620851,131.1519648
5070 DATA "Y",27000,47.0
34799,119.443953,"Z",410
00,50.3629731,127.212904
3
```

```
5080 DATA 7930,3,59.5917
27,45.102747,"W",11000,6
4.542658,23.552175
5090 DATA "X",21000,62.1
75964,7.0426538,"Z",4300
0,46.463218,53.102816
5100 DATA "*7930",3,24.1
707888,-153.5053232,"X",
11000,42.4437104,-143.43
09245
5110 DATA "Y",30000,26.3
624975,-128.0856445,"Z",
49000,9.3245789,-138.095
497
5120 DATA 7960.2,63.1942
814,142.48319,"X",11000,
57.262021,152.2211225
5130 DATA "Y",26000,55.2
620851,131.1519648
5140 DATA 7970,4,62.1759
64,7.0426538,"W",26000,5
4.4829872,-8.1736312
5150 DATA "X",11000,68.3
80615,-14.2747,"Y",46000
,64.542658,23.552175
5160 DATA "Z",60000,70.5
45261,8.435869
5170 DATA 7980.4,30.5938
74,85.1009305,"W",11000,
30.4333018,90.49436
5180 DATA "X",23000,26.3
155006,97.5000093,"Y",43
000,27.0158393,80.065342
9
5190 DATA "Z",59000,34.0
346081,77.5446654
5200 DATA 7990,3,38.5220
587,-16.4306159,"X",1100
0,35.3120787,-12.3130245
5210 DATA "Y",29000,40.5
02095,-27.520152,"Z",470
00,42.0336515,-3.1215512
5220 DATA 8970,3,39.5107
54,87.291214,"W",11000,3
0.593874,85.1009305
5230 DATA "X",20000,42.4
250683,76.4933862,"Y",44
000,48.3649844,94.331846
9
5240 DATA 9940,3,39.3306
621,118.495637
5250 DATA "W",11000,47.0
34799,119.443953,"X",270
00,38.465699,122.2944529
5260 DATA "Y",40000,35.1
91818,114.4817435
5270 DATA 9960,4,42.4250
683,76.4933862,"W",11000
,46.4827199,67.5537713
5280 DATA "X",25000,41.1
51193,69.583909,"Y",3900
0,34.0346081,77.5446654
5290 DATA "Z",54000,39.5
10754,87.291214
5300 DATA 9970,4,24.4803
597,-141.1930303,"W",110
00,24.1707808,-153.58532
32
5310 DATA "X",30000,42.4
437104,-143.4309245,"Y",
55000,26.3624975,-128.08
56445
5320 DATA "Z",75000,9.32
45789,-138.095497
5330 DATA 9990,3,57.0912
265,170.1506789,"X",1100
0,52.494404,-173.1048974
5340 DATA "Y",29000,65.1
440306,166.531255,"Z",43
000,57.262021,152.221122
5
```

III. THE SHARP PC-1500 (RADIO SHACK TRS-80 PC-2).

PC-1500 (TRS-80 PC-2) USER INSTRUCTIONS.

The options are labeled 1 through 9, A or H. The H (Help) option will review options 1 - 9 & A. To step through the HELP menu, use the ENTER key. Option 6 (TWO POINT HEAD & DIST) is a stand-alone option which may be used by itself. For LORAN fixing, Option 8 must be selected first to load the station GRI's. If Option 8 is not used, then any option requiring the GRI's will automatically enter Option 8 first. Option 1 (LORAN FIX) must be selected at least once before Option 2 (ALTERNATE SOLN) can be selected. Once the GRI's are loaded, any of the remaining options may be used at any time. When first run, the ASF Correction Factors are set to zero; if they are subsequently entered as non-zero values they will remain set until either changed manually, by selection of Option 9, or until the program is RUN once more. In all cases, South latitudes and East longitudes must be negative for input and will be labeled by a minus sign '-' on output. For ease of reference the options are listed by number rather than by sequence of selection.

INSTRUCTION	DISPLAY	INPUT
Run Program		RUN.10
	NEXT OPTION (Help)?	
1. LORAN FIX		1
ITD for 1st GRI	ITD FOR gri 1?	1st ITD [ENTER]
ITD for 2nd GRI	ITD FOR gri 2?	2nd ITD [ENTER]
Lat of fix	LAT = dd°mm'ss"	[ENTER]
Long of fix	LONG = ddd°mm'ss"	[ENTER]
	NEXT OPTION (Help)?	
2. ALTERNATE SOLN		2
Lat of fix	LAT = dd°mm'ss"	[ENTER]
Long of fix	LONG = ddd°mm'ss"	[ENTER]
	NEXT OPTION (Help)?	
3. INPUT DEST LAT/LONG		3
	DEST LAT dd.mmss?	Lat of dest. [ENTER]
	DEST LONG ddd.mmss?	Long of dest. [ENTER]
	NEXT OPTION (Help)?	
4. HEAD & DIST TO DEST		4
Heading to dest.	HEADING = dd°mm'ss"	[ENTER]
Dist. to dest.	DISTANCE = mmm.ff n.mi.	[ENTER]
	NEXT OPTION (Help)?	

INSTRUCTION	DISPLAY	INPUT
5. PREDICT ITDs		5
	LAT dd.mmss?	Lat [ENTER]
	LONG ddd.mmss?	Long [ENTER]
1st ITD	ITD FOR gri 1 = xxxxx.xx µs	[ENTER]
2nd ITD	ITD FOR gri 2 = xxxxx.xx µs	[ENTER]
	New Lat/Lon or	
	Return to menu	N repeats Option 5
		R goes to next line
	NEXT OPTION (Help)?	
6. TWO POINT HEAD & DIST		6
	ORIGIN LAT dd.mmss?	Lat of origin [ENTER]
	ORIGIN LONG ddd.mmss?	Long of origin [ENTER]
	DEST LAT dd.mmss?	Lat of dest. [ENTER]
	DEST LONG ddd.mmss?	Long of dest. [ENTER]
Heading to dest.	HEADING = dd°mm'ss"	[ENTER]
Dist. to dest.	DISTANCE = mmm.ff n.mi.	[ENTER]
	NEXT OPTION (Help)?	
7. CALIBRATE		7
	LAT dd.mmss?	Lat of fix [ENTER]
	LONG ddd.mmss?	Long of fix [ENTER]
	ITD FOR gri 1?	1st ITD [ENTER]
	ITD FOR gri 2?	2nd ITD [ENTER]
	NEXT OPTION (Help)?	
8. NEW STA. IDs		8
	1st GRI?	Sta. ID [ENTER]
	2nd GRI?	Sta. ID [ENTER]
	NEXT OPTION (Help)?	
9. ASF Corrections		9
	ASF FOR gri 1?	1st ASF [ENTER]
	ASF FOR gri 2?	2nd ASF [ENTER]
	NEXT OPTION (Help)?	
A. STOP		A
	>	

PC-1500 (TRS-80 PC-2) SAMPLE PROBLEM 1

You are sailing off of the coast of California. Your destination is Moss Landing at about 36°48'N and 121°47'W. Your present ITD from station pair GRI 9940W is 16019 and your ITD from station pair GRI 9940Y is 42585. What is your current position and what is the heading and distance from your current position to Moss Landing? We assume that the GRI's 9940W and 9940Y have not yet been loaded.

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?	3	Input destination.
DEST LAT dd.mmss?	36.48 [ENTER]	36°48'
DEST LONG ddd.mmss?	121.47 [ENTER]	121°47'
NEXT OPTION (Help)?	8	Input station ID's.
1st GRI?	9940W [ENTER]	
2nd GRI?	9940Y [ENTER]	
NEXT OPTION (Help)?	1	Compute a fix.
ITD FOR 9940W?	16019	
ITD FOR 9940Y?	42585	
LAT = 39 14 19	[ENTER]	Latitude of fix.
LONG = 115 50 52	[ENTER]	Longitude of fix.

This fix is in Nevada. There are always two solutions to the LORAN equations. The navigator must select the correct one.

NEXT OPTION (Help)?	2	Select alternate soln.
LAT = 35 00 01	[ENTER]	Latitude of fix.
LONG = 125 00 09	[ENTER]	Longitude of fix.

This fix is in the Pacific. The navigator knows it is the correct fix because of his estimate of where he should be.

NEXT OPTION (Help)?	4	Find heading & distance to destination.
HEADING = 54 34 11	[ENTER]	Heading to Moss Landing.
DISTANCE = 190.38 n.mi.	[ENTER]	Distance to Moss Landing.
NEXT OPTION (Help)?		Repeat with new option or press A to quit.

PC-1500 (TRS-80 PC-2) SAMPLE PROBLEM 2

How far, and in what direction, is Corvallis, Oregon (44°34'N, 123°16'W) from Cupertino, California (37°19'N, 122°02'W)?

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?	6	Two point distance and heading.
ORIGIN LAT dd.mmss?	37.19 [ENTER]	37°19'
ORIGIN LONG ddd.mmss?	122.02 [ENTER]	122°02'
DEST LAT dd.mmss?	44.34 [ENTER]	44°34'
DEST LONG ddd.mmss?	123.16 [ENTER]	123°16'
HEADING = 353 02 59	[ENTER]	
DISTANCE = 438.32 n.mi.	[ENTER]	
NEXT OPTION (Help)?		Repeat with new option or press A to quit.

PC-1500 (TRS-80 PC-2) SAMPLE PROBLEM 3

Suppose that you want to know what ITD's you would expect to receive at 35° North, 125° West and at 36°27' North, 126°54' West from 9940W and 9940Y. To determine these ITD's, proceed as follows (assume that the GRI's have been loaded as in Sample Problem 1):

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?	5	Predict ITD's.
LAT dd.mmss?	35 [ENTER]	35°
LONG ddd.mmss?	125 [ENTER]	125°
ITD FOR 9940W = 16019.35	[ENTER]	
ITD FOR 9940Y = 42584.71	[ENTER]	
New Lat/Lon or Return to menu?	N	
LAT dd.mmss?	36.27 [ENTER]	36°27'
LONG ddd.mmss?	126.54 [ENTER]	126°54'
ITD FOR 9940W = 15572.32	[ENTER]	
ITD FOR 9940Y = 43006.15	[ENTER]	
New Lat/Lon or Return to menu?	R	
NEXT OPTION (Help)?		Repeat with new option or press A to quit.

PC-1500 (TRS-80 PC-2) SAMPLE PROBLEM 4

Suppose you are receiving an ITD of 16308 from 9940W and 42800 from 9940Y. These ITD's would tell you that your location is 36°47'55"N and 121°47'11"W. However, you know that your position is benchmarked to be at 36°47'36"N and 121°46'58"W, and you wish to calibrate your PC-1500 so that the ITD's of 16308 and 42800 will give you the latter fix instead of the former. Proceed as follows (assume the GRI's have been loaded as in Sample Problem 1):

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?	7	Calibrate.
LAT dd.mmss?	36.4736 [ENTER]	36°47'36"
LONG ddd.mmss?	121.4658 [ENTER]	121°45'58"
ITD FOR 9940W?	16308 [ENTER]	
ITD FOR 9940Y?	42800 [ENTER]	

The station baselines have now been modified to achieve calibration. Now, reenter 16038 and 42800 into the fixing routine to test the calibration. Calibration does not modify the permanent station data stored in the PC-1500. The calibration remains effective until the GRI's are reloaded by Option 8. NOTE: The affect of calibration on the accuracy of fixes far removed from the benchmark has not been studied. The user should use the calibration option with caution.

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?	1	Compute a fix.
ITD FOR 9940W?	16308 [ENTER]	
ITD FOR 9940Y?	42800 [ENTER]	
LAT = 36 47 35	[ENTER]	Lat of fix.
LONG = 121 46 59	[ENTER]	Long of fix.

The small discrepancy between this fix and the benchmark is due to assumptions in the fixing algorithm. If higher precision is required, the ASF Correction factor may be used (see Sample Problem 5). Note that you may need to use the Alternate Solution Option 2 if the fix obtained above is near 38°52'57"N and 116°51'11'W.

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?		Repeat with new option or press A to quit.

PC-1500 (TRS-80 PC-2) SAMPLE PROBLEM 5

Suppose you are receiving an ITD of 12153.31 microseconds from 9960W and 44451.83 microseconds from 9960Y. These ITD's would tell you that your location is 44°15'05"N and 67°25'23"W. Entering the ASF Correction Tables [Ref. 5,6] with these readings, the ASF Correction for GRI 9960W at 44°15'N and 67°25'W is 1.5 microseconds. Similiarly, the ASF Correction for GRI 9960Y at these coordinates is 2.7 microseconds. Enter these corrections into your PC-1500 and recompute your position. (Load the GRI's 9960W and 9960Y using Option 8).

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
NEXT OPTION (Help)?	9	ASF Correction.
ASF FOR 9960W?	1.5 [ENTER]	
ASF FOR 9960Y?	2.7 [ENTER]	
NEXT OPTION (Help)?	1	Compute a fix.
ITD FOR 9960W?	12153.31 [ENTER]	
ITD FOR 9940Y?	44451.83 [ENTER]	
LAT = 44 15 26	[ENTER]	
LONG = 67 26 26	[ENTER]	
NEXT OPTION (Help)?		Repeat with new option or press A to quit.

These ASF Corrections have been entered into the computer. The range of their validity must be checked with the ASF Correction tables and reentered if they change. NOTE: If you are using the ASF Correction Tables and if you wish to calibrate to a benchmark position, you should first enter the ASF Corrections for your benchmark and then use the calibration Option 7 (see Sample Problem 4).

PC-1500 (TRS-80 PC-2) PROGRAM LISTING

```
10:REM  LORAN-C R
   OUTINE. Rev 06
   -23-83. 1730 H
   OURS.
20:N9=15:REM  N9=
   # OF MASTER ST
   ATIONS
25:DIM W$(4)*1,D9
   (4),PI(4),LI(4
   ),G$(2)*6,D(2)
   ,P(2,2),L(2,2)
   ,B(2),T(3),Z(2
   ,2),A(2)
26:DIM G(2)
30:RADIAN :C0=1/2
   98.26:A0=-1:RD
   =PI /180:G1$="
   ":GOTO 120
40:X=INT (M*X+.5)
   /M:RETURN
50:P=129.04398/T-
   .40758+.645764
   38E-3*T:RETURN
60:P=2.7412979/T-
   .011402+.32774
   624E-3*T
70:C$=INKEY$ :IF
   C$="" THEN 70
80:C=ASC (C$):C$=
   CHR$ (C-32*(C>
   90))
90:FOR C=1TO LEN
   (C0$):IF C$=
   MID$ (C0$,C,1)
   THEN RETURN
100:NEXT C:GOTO 70
120:PAUSE "NEXT OP
   TION (Help)?":
   C0$="123456789
   AH":GOSUB 70:
   PAUSE " "
130:ON CGOSUB 910,
   950,1010,1040,
   1090,990,1200,
   190,1320,530,1
   40:GOTO 120
140:PRINT '1 - LOR
   AN FIX':PRINT
   '2 - ALTERNATE
    SOLN':PRINT "
   3 -INPUT DEST
   LAT/LONG'
150:PRINT '4 - HEA
   D & DIST TO FI
   X':PRINT '5 -
   PREDICT TDs'
160:PRINT '6 - TWO
    POINT DIST &
   HEAD :PRINT '7
    - CALIBRATE'
170:PRINT '8 - NEW
    STA. IDs':
   PRINT '9 - ASF
    Connections':
   PRINT 'A - STO
   P'
180:RETURN
185:IF G1$<>' THEN
   RETURN
190:F0=1:N=1.INPUT
   '1st GRI? ';I$
   :PAUSE '
200:GOSUB 380:
   GOSUB 390.IF F
   0=2THEN 190
210:F0=1:N=2:INPUT
   '2nd GRI?  ;I$
   :PAUSE ' ':
   GOSUB 380
220:IF A$=I9$THEN
   GOSUB 470:IF F
   0=1THEN 250
240:GOSUB 390:IF F
   0=2THEN 210
250:F1=1:F2=1:IF G
   1$=G2$THEN 300
260:IF P(1,1)=P(1,
   2)AND L(1,1)=L
   (1,2)THEN 310
270:F2=-1:IF P(1,1
   )=P(2,2)AND L(
   1,1)=L(2,2)
   THEN 310
```

```
280:F1=-1:IF P(2,1
    )=P(2,2)AND L(
    2,1)=L(2,2)
    THEN 310
290:F2=1:IF P(2,1)
    =P(1,2)AND L(2
    ,1)=L(1,2)THEN
    310
300:PRINT "ERROR:
    NO TRIPLET.":
    GOTO 190
310:FOR I=1TO 2:P1
    =P(1,I):L1=L(1
    ,I):P2=P(2,I):
    L2=L(2,I)
320:PAUSE "Working
    ":GOSUB 330:
    NEXT I:C(1)=0:
    C(2)=0:RETURN
330:GOSUB 650:B(I)
    =S0:Z(1,I)=Z1:
    Z(2,I)=Z2
340:T=2*282.3593*S
    0
350:IF T>=537THEN
    GOSUB 50
360:IF T<537THEN
    GOSUB 60
370:T(I)=T+P:
    RETURN
380:L=LEN (I$):A$=
    LEFT$ (I$,L-1)
    :B$=RIGHT$ (I$
    ,1):B=ASC (B$)
    :B$=CHR$ (B-32
    *(B>90)):
    RETURN
390:N8=1:RESTORE
400:READ I9$,N0,P0
    ,L0
410:FOR I=1TO N0:
    READ W$(I),D9(
    I),P1(I),L1(I)
    :NEXT I
420:IF I9$<>A$THEN
    450
430:GOSUB 470:IF F
    0=2THEN 460
440:RETURN
450:N8=N8+1:IF N8<
    =N9THEN 400
460:PAUSE I$;" IS
    NOT CATALOGED
    :F0=2:RETURN
470:FOR I=1TO N0:
    IF W$(I)=B$
    THEN 490
480:NEXT I:F0=2:
    RETURN
490:IF N=1THEN LET
    C1$=I$:C$(1)=I
    $
500:IF N=2THEN LET
    C2$=I$:C$(2)=I
    $
510:D(N)=D9(I):X=R
    D*DEG (-P):
    GOSUB 1270:P1(
    ,N)=X:L(1,N)=R
    D*DEG (-L0)
520:X=RD*DEG (P1(I
    )):GOSUB 1270:
    P(2,N)=X:L(2,N
    )=RD*DEG (L1(I
    )):RETURN
530:PAUSE "END"
540:REM  DIR SOLN
550:Z8=SIN (Z1):Z9
    =COS (Z1):P8=
    SIN (P1):P9=
    COS (P1):M=-Z8
    *P9:C1=C0*M:C2
    =C0*(1-M*M)/4
560:D=(1-C2)*(1-C2
    -C1*M):P=C2*(1
    +C1*M/2)/D:N=P
    9*Z9
570:YY=N:XX=P8:
    GOSUB 1260:S1=
    AN:D0=S0/D:U=2
    *(S1-D0):W=1-2
    *P*COS (U):V=
    COS (U+D0)
```

PC-1500 (TRS-80 PC-2) PROGRAM LISTING (cont.)

```
580:X=C2*C2*SIN (D
    0)*COS (D0*(2*
    U*U-1)):Y=2*P*
    U*W*SIN (D0)
590:S2=D0+X-Y:S8=
    SIN (S2):S9=
    COS (S2):K=SQR
    (M*M+(N*S9-P8*
    S8)^2)
600:P2=ATN ((P8*S9
    +N*S8)/K)
610:YY=-S8*Z8:XX=P
    9*S9-P8*S8*Z9:
    GOSUB 1260:S3=
    AN
620:H=C1*(1-C2)*S2
    -C1*C2*S8*COS
    (S1+S1-S2):L2=
    L1+S3-H
630:YY=-M:XX=-(N*S
    9-P8*S8):GOSUB
    1260:Z2=AN:
    RETURN
640:REM  REV SOLN
650:L3=L2-L1:P3=(P
    2-P1)/2:P4=(P1
    +P2)/2
660:P6=SIN (P3):P7
    =COS (P3):P8=
    SIN (P4):P9=
    COS (P4)
670:H=P7*P7-P8*P8:
    L=P6*P6+H*SIN
    (L3/2)^2:D0=2*
    ASN (SQR (L))
680:U=2*P8*P8*P7*P
    7/(1-L):V=2*P6
    *P6*P9*P9/L:X=
    U+V:Y=U-V:T=D0
    /SIN (D0):D=4*
    T*T
690:E=2*COS (D0):A
    =D*E:C=T-(A-E)
    /2:N1=X*(A+C*X
    ):B=D+D:N2=Y*(
    B+E*Y):N3=D*X*
    Y
700:D2=C0*C0*(N1-N
    2+N3)/64:D1=C0
    *(T*X-Y)/4:S0=
    (T-D1+D2)*SIN
    (D0)
710:M=32*T-(20*T-A
    )*X-(B+4)*Y
720:F=Y+Y-E*(4-X):
    G=C0*(T/2+C0*M
    /64):Q=-F*G*
    TAN (L3)/4
730:L4=(L3+Q)/2:L8
    =SIN (L4):L9=
    COS (L4)
740:YY=P6*L9:XX=P9
    *L8:GOSUB 1260
    :T1=AN:YY=-P7*
    L9:XX=P8*L8:
    GOSUB 1260:T2=
    AN
750:M=P1 +P1 :X=T1
    +T2:GOSUB 1250
    :Z1=X:X=T1-T2:
    GOSUB 1250:Z2=
    X:RETURN
760:REM  FIXING RO
    UTINE
770:A1=F1*SIN (A(1
    )):B1=COS (A(1
    ))-COS (B(1)):
    C1=SIN (B(1))
780:A2=F2*SIN (A(2
    )):B2=COS (A(2
    ))-COS (B(2)):
    C2=SIN (B(2))
790:E1=Z(1,1):IF F
    1=-1THEN LET E
    1=Z(2,1)
800:E2=Z(1,2):IF F
    2=-1THEN LET E
    2=Z(2,2)
810:C=B1*C2*COS (E
    2)-B2*C1*COS (
    E1):S=B1*C2*
    SIN (E2)-B2*C1
    *SIN (E1)
```

```
820:K=B2*A1-B1*A2:
    R=SQR (C*C+S*S
    ):YY=S:XX=C:
    GOSUB 1260:G=A
    N
830:Z=G+A0*ACS (K/
    R):YY=B2:XX=C2
    *COS (Z-E2)+A2
    :GOSUB 1260:S0
    =AN
840:IF F2=1THEN
    LET P1=P(1,2):
    L1=L(1,2)
850:IF F2=-1THEN
    LET P1=P(2,2):
    L1=L(2,2)
860:Z1=Z:GOSUB 550
    :P0=P2:L0=L2:P
    =ATN (TAN (P0)
    /(1-C0))
870:P=P/RD:X=L0/RD
    :M=360:GOSUB 1
    250:L=X:IF L>1
    80THEN LET L=L
    -360
880:X=P:GOSUB 1280
    :P$=C$:X=L:
    GOSUB 1280
890:PRINT "LAT = "
    ;P$:PRINT "LON
    G = ";C$:
    RETURN
900:REM  OPT 1
910:GOSUB 185:FOR
    I=1TO 2
920:PAUSE "ITD FOR
     ";G$(I);:
    INPUT "? ";A:
    PAUSE :PAUSE "
     ":A=A+G(I)-D(
    I)-T(I):IF ABS
    (A)<T(I)THEN 9
    40
930:PRINT "ITD NOT
     VALID FOR ";G
    $(I):GOTO 920
940:A(I)=A/2129[illegible].P
    736:NEXT I:
    GOSUB 770:
    RETURN
950:IF A0=1THEN
    LET A0=-1:GOTO
    970
960:A0=1
970:GOSUB 770:
    RETURN
980:REM  OPT 6
990:INPUT "ORIGIN
    LAT dd.mmss? "
    ;P:INPUT "ORIG
    IN LONG ddd.mm
    ss? ";L
 1000:X=RD*DEG P
     :GOSUB 1270:
     P0=X:L0=RD*
     DEG (L):
     GOSUB 1010:
     GOSUB 1040:
     RETURN
 1010:INPUT "DEST
     LAT dd.mmss? "
       ;P:INPUT "
     DEST LONG dd
     d.mmss? ";L
 1020:X=RD*DEG P
     :GOSUB 1270:
     P5=X:L5=RD*
     DEG (L):
     RETURN
 1030:REM  OPT 4
 1040:P1=P0:L1=L0:
     P2=P5:L2=L5:
     GOSUB 650
 1050:M=360:X=Z1/R
     D:GOSUB 1250
     :GOSUB 1280
 1060:PRINT "HEADI
     NG = ";C$:M=
     100:X=3443.9
     17*S0:GOSUB
     40:PRINT "DI
     STANCE = ";X
     ;" n.mi."
 1070:RETURN
```

```
1Ø8Ø:REM  OPT 5
1Ø9Ø:GOSUB 185:
     GOSUB 117Ø:
     FOR K=1TO 2:
     I9=T(K)+D(K)
11ØØ:P2=P(2,K):L2
     =L(2,K):
     GOSUB 65Ø:I=
     3:GOSUB 34Ø:
     I9=I9+T(3)
111Ø:P2=P(1,K):L2
     =L(1,K):
     GOSUB 65Ø:I=
     3:GOSUB 34Ø:
     I9=I9-T(3)
112Ø:M=1ØØ:X=I9:
     GOSUB 4Ø
113Ø:PRINT "ITD F
     OR ";G$(K);
     "=";X:PAUSE
     "":NEXT K
114Ø:PAUSE "New l
     at/long on R
     eturn to men
     u?":C0$="NR"
     :GOSUB 7Ø
115Ø:IF C=1THEN 1
     Ø9Ø
116Ø:RETURN
117Ø:INPUT "LAT d
     d.mm.ss? ";P
     1:INPUT "LON
     G ddd.mmss?
     ";L1:PAUSE "
     "
118Ø:X=RD*DEG (P1
     ):GOSUB 127Ø
     :P1=X:L1=RD*
     DEG (L1):
     RETURN
119Ø:REM  OPT 7
12ØØ:GOSUB 185:
     GOSUB 117Ø:
     FOR K=1TO 2
121Ø:PAUSE "ITD F
     OR ";G$(K):
     INPUT "? ",I
     9:PAUSE :
     PAUSE " ":I9
     =I9-D(K)
122Ø:P2=P(2,K):L2
     =L(2,K):
     GOSUB 65Ø:I=
     3:GOSUB 34Ø:
     I9=I9-T(3)
123Ø:P2=P(1,K):L2
     =L(1,K):
     GOSUB 65Ø:I=
     3:GOSUB 34Ø:
     T(K)=I9-T(3)
     +D(K)
124Ø:NEXT K:
     RETURN
125Ø:X=X-M*INT (X
     /M):RETURN
126Ø:AN=ATN (YY/(
     XX+1E-3*(XX=
     Ø)))+PI *(XX
     <Ø):RETURN
127Ø:X=ATN ((1-E2
     )*TAN (X)):
     RETURN
128Ø:C$=" ":IF X<
     ØTHEN LET C$
     ="-":X=-X
129Ø:X=X+1/72ØØ:X
     Ø=INT (X):C$
     =C$+STR$ (XØ
     )+" "
13ØØ:X=6Ø*(X-XØ):
     XØ=INT (X):X
     $=STR$ (1ØØ+
     XØ):C$=C$+
     RIGHT$ (X$,2
     )+" "
131Ø:X=6Ø*(X-XØ):
     XØ=INT (X):X
     $=STR$ (1ØØ+
     XØ):C$=C$+
     RIGHT$ (X$,2
     )+" ":RETURN
```

```
1320:GOSUB 185:
     PAUSE "ASF F
     OR ";G$(1):
     INPUT "? ";[illegible]
     (1):PAUSE "":
     PAUSE "
1330:PAUSE "ASF F
     OR ";G$(2):
     INPUT "? ";[illegible]
     (2):PAUSE "":
     PAUSE "":
     RETURN
5000:DATA "4990",
     [illegible],16.44[illegible],
     [illegible].3[illegible]
     [illegible],11000,20.[illegible]
     44916,15[illegible]
     [illegible]
5010:DATA "[illegible]",29[illegible]
     00,22.[illegible]34[illegible]
     ,178.[illegible]
5020:DATA "[illegible]",
     [illegible],46.482[illegible]
     ,6[illegible]
     X",1100[illegible]
     [illegible]
     [illegible]
5030:DATA "[illegible]
     00,4[illegible]
     ,5[illegible].102816
5040:DATA "5920",
     3,36.1105292
     ,-129.202722
     9,"W",11000,
     42.4437104,-
     143.4309245
5050:DATA "X",310
     00,35.022382
     1,-126.32267
     4,"Z",42000,
     26.3624975,-
     128.0856445
5060:DATA "5990",
     3,51.575878,
     122.220224,"
     X",11000,55.
     2620851,131.
     1519648
5070:DATA "Y",270
     00,42.034793
     ,119.443[illegible]
     Z",41000,50
     .362973[illegible]
     2129043
5080:DATA "7930",
     [illegible],59.591[illegible]
     45.102742,"W
     ",11000,64.5
     42656,23.55
     175
5090:DATA "X",210
     00,61.[illegible]
     ,[illegible].0420[illegible]
     Z",43000,46.
     463216,53.10
     2816
5100:DATA "7930"
     ,3,24.1[illegible]
     6,-155.5[illegible]
     [illegible],"Y",11000
     ,42.443[illegible]
     [illegible]143.4309[illegible]
5110:DATA "Y",300
     00,26.362[illegible]
     5,-128.085[illegible]
     45,"[illegible]",49000
     ,[illegible].3241[illegible]
     138.08549[illegible]
5120:DATA "7960",
     2,63.1942914
     ,142.48313,"
     X",11000,57.
     262021,152.2
     211225
5130:DATA "Y",260
     00,55.262085
     1,131.151964
     8
5140:DATA "7970",
     4,62.175964,
     7.0426538,"W
     ",26000,54.4
     829872,-8.17
     36312
```

PC-1500 (TRS-80 PC-2) PROGRAM LISTING (cont.)

```
5150:DATA "X",110
     00,68.380615
     ,-14.2242, "
     ",46000,64.5
     42658,23.552
     175
5160:DATA "Z",600
     00,70.545261
     ,8.435869
5170:DATA "7980",
     4,30.593874,
     85.1009305,
     W",11000,30.
     4333018,90.4
     9438
5180:DATA "X",230
     00,26.315500
     6,97.5000093
     ,"Y",43000,2
     7.0158393,80
     .0653429
5190:DATA "Z",590
     00,34.034608
     1,72.5446654
5200:DATA "7990",
     3,38.5220587
     ,-16.4306159
     , "Y",11000,3
     5.3120787,-1
     2.3130245
5210:DATA "Y",290
     00,40.582095
     ,-27.520152,
     "Z",47000,42
     .0336515,-3.
     1215512
5220:DATA "8970",
     3,39.510754,
     87.291214,"W
     ",11000,30.5
     93874,85.100
     9305
5230:DATA "X",280
     00,42.425060
     3,76.4933862
     ,"Y",44000,4
     8.3649844,94
     .3318469
5240:DATA "9940",
     3,39.3306621
     ,118.495637,
     "W",11000,47
     .034799,119.
     443953
5250:DATA "X",270
     00,38.46599,
     121.2944529,
     "Y",40000,35
     .191816,114.
     4817435
5270:DATA "9960",
     4,42.4250603
     ,76.4933862,
     "W",11000,45
     .4827199,67.
     5537213
5280:DATA "Y",250
     00,41.151193
     ,69.583909,
     "Z",33000,34.
     0346081,72.1
     446654
5290:DATA "Z",540
     00,39.510754
     ,87.291214
5300:DATA "9970",
     4,24.4803597
     ,-141.193030
     3,"W",11000,
     24.1707888,-
     153.5853232
```

```
5310:DATA "X",300
     00,42.443710
     4,-143.43092
     45,"Y",55000
     ,26.3624975,
     -128.0856445
5320:DATA "Z",750
     00,9.3245789
     ,-138.095497
5330:DATA '9990',
     3,57.09:265,
     170.1506789,
     "X",11000,52
     .494404,-173
     .1048974
5340:DATA "Y",290
     00,65.144030
     6,166.531255
     ,'Z',43000,5
     7.262021,152
     .2211225
```

IV. THE RADIO SHACK TRS-80 MODEL 100.

TRS-80 MODEL 100 USER INSTRUCTIONS.

The options are labeled 1 through 9 or A. Option 6 (TWO POINT HEAD & DIST) is a stand-alone option which may be used by itself. For LORAN fixing, Option 8 must be selected first to load the station GRI's. If Option 8 is not used, then any option requiring the GRI's will automatically enter Option 8 first. Option 1 (LORAN FIX) must be selected at least once before Option 2 (ALTERNATE SOLN) can be selected. Once the GRI's are loaded, any of the remaining options may be used at any time. When first run, the ASF Correction Factors are set to zero; if they are subsequently entered as non-zero values they will remain set until either changed manually, by selection of Option 9, or until the program is RUN once more. In all cases, South latitudes and East longitudes must be negative for input and will be labeled by a minus sign '-' on output. For ease of reference the options are listed by number rather than by sequence of selection.

INSTRUCTION	DISPLAY	INPUT
Run Program	Select LORAN.BA	[ENTER]
	OPTION?	
1. LORAN FIX		1
ITD for 1st GRI	ITD FOR gri 1?	1st ITD [ENTER]
ITD for 2nd GRI	ITD FOR gri 2?	2nd ITD [ENTER]
Lat of fix	LAT = dd°mm'ss"	[ENTER]
Long of fix	LONG = ddd°mm'ss"	[ENTER]
	OPTION?	
2. ALTERNATE SOLN		2
Lat of fix	LAT = dd°mm'ss"	[ENTER]
Long of fix	LONG = ddd°mm'ss"	[ENTER]
	OPTION?	
3. INPUT DEST LAT/LONG		3
	DEST LAT dd.mmss?	Lat of dest. [ENTER]
	DEST LONG ddd.mmss?	Long of dest. [ENTER]
	OPTION?	
4. HEAD & DIST TO DEST		4
Heading to dest.	HEADING = dd°mm'ss"	[ENTER]
Dist. to dest.	DISTANCE = mmm.ff n.mi.	[ENTER]
	OPTION?	

INSTRUCTION	DISPLAY	INPUT
5. PREDICT ITDs		5
	LAT dd.mmss?	Lat [ENTER]
	LONG ddd.mmss?	Long [ENTER]
1st ITD	ITD FOR gri 1 = xxxxx.xx μs	[ENTER]
2nd ITD	ITD FOR gri 2 = xxxxx.xx μs	[ENTER]
	New Lat/Lon or	
	Return to menu	N repeats Option 5
		R goes to next line
	OPTION?	
6. TWO POINT HEAD & DIST		6
	ORIGIN LAT dd.mmss?	Lat of origin [ENTER]
	ORIGIN LONG ddd.mmss?	Long of origin [ENTER]
	DEST LAT dd.mmss?	Lat of dest. [ENTER]
	DEST LONG ddd.mmss?	Long of dest. [ENTER]
Heading to dest.	HEADING = dd°mm'ss"	[ENTER]
Dist. to dest.	DISTANCE = mmm.ff n.mi.	[ENTER]
	OPTION?	
7. CALIBRATE		7
	LAT dd.mmss?	Lat of fix [ENTER]
	LONG ddd.mmss?	Long of fix [ENTER]
	ITD FOR gri 1?	1st ITD [ENTER]
	ITD FOR gri 2?	2nd ITD [ENTER]
	OPTION?	
8. NEW STA. IDs		8
	1st GRI?	Sta. ID [ENTER]
	2nd GRI?	Sta. ID [ENTER]
	OPTION?	
9. ASF Corrections		9
	ASF FOR gri 1?	1st ASF [ENTER]
	ASF FOR gri 2?	2nd ASF [ENTER]
	OPTION?	
A. STOP		A
	>	

TRS-80 MODEL 100 SAMPLE PROBLEM 1

You are sailing off of the coast of California. Your destination is Moss Landing at about 36°48'N and 121°47'W. Your present ITD from station pair GRI 9940W is 16019 and your ITD from station pair GRI 9940Y is 42585. What is your current position and what is the heading and distance from your current position to Moss Landing? We assume that the GRI's 9940W and 9940Y have not yet been loaded.

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
OPTION?	3	Input destination.
DEST LAT dd.mmss?	36.48 [ENTER]	36°48'
DEST LONG ddd.mmss?	121.47 [ENTER]	121°47'
OPTION?	8	Input station ID's.
1st GRI?	9940W [ENTER]	
2nd GRI?	9940Y [ENTER]	
OPTION?	1	Compute a fix.
ITD FOR 9940W?	16019	
ITD FOR 9940Y?	42585	
LAT = 39°14'19"	[ENTER]	Latitude of fix.
LONG = 115°50'52"	[ENTER]	Longitude of fix.

This fix is in Nevada. There are always two solutions to the LORAN equations. The navigator must select the correct one.

OPTION?	2	Select alternate soln.
LAT = 35°00'01"	[ENTER]	Latitude of fix.
LONG = 125°00'09"	[ENTER]	Longitude of fix.

This fix is in the Pacific. The navigator knows it is the correct fix because of his estimate of where he should be.

OPTION?	4	Find heading & distance to destination.
HEADING = 54°34'11"	[ENTER]	Heading to Moss Landing.
DISTANCE = 190.38 n.mi.	[ENTER]	Distance to Moss Landing.
OPTION?		Repeat with new option or press A to quit.

TRS-80 MODEL SAMPLE PROBLEM 2

How far, and in what direction, is Corvallis, Oregon (44°34'N, 123°16'W) from Cupertino, California (37°19'N, 122°02'W)?

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
OPTION?	6	Two point distance and heading.
ORIGIN LAT dd.mmss?	37.19 [ENTER]	37°19'
ORIGIN LONG ddd.mmss?	122.02 [ENTER]	122°02'
DEST LAT dd.mmss?	44.34 [ENTER]	44°34'
DEST LONG ddd.mmss?	123.16 [ENTER]	123°16'
HEADING = 353°02'59"	[ENTER]	
DISTANCE = 438.32 n.mi.	[ENTER]	
OPTION?		Repeat with new option or press A to quit.

TRS-80 MODEL SAMPLE PROBLEM 3

Suppose that you want to know what ITD's you would expect to receive at 35° North, 125° West and at 36°27' North, 126°54' West from 9940W and 9940Y. To determine these ITD's, proceed as follows (assume that the GRI's have been loaded as in Sample Problem 1):

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
OPTION?	5	Predict ITD's.
LAT dd.mmss?	35 [ENTER]	35°
LONG ddd.mmss?	125 [ENTER]	125°
ITD FOR 9940W = 16019.35	[ENTER]	
ITD FOR 9940Y = 42584.71	[ENTER]	
New Lat/Lon or Return to menu?	N	
LAT dd.mmss?	36.27 [ENTER]	36°27'
LONG ddd.mmss?	126.54 [ENTER]	126°54'
ITD FOR 9940W = 15572.32	[ENTER]	
ITD FOR 9940Y = 43006.15	[ENTER]	
New Lat/Lon or Return to menu?	R	
OPTION?		Repeat with new option or press A to quit.

TRS-80 MODEL 100 SAMPLE PROBLEM 4

Suppose you are receiving an ITD of 16308 from 9940W and 42800 from 9940Y. These ITD's would tell you that your location is 36°47'55"N and 121°47'11"W. However, you know that your position is benchmarked to be at 36°47'36"N and 121°46'58"W, and you wish to calibrate your Model 100 so that the ITD's of 16308 and 42800 will give you the latter fix instead of the former. Proceed as follows (assume the GRI's have been loaded as in Sample Problem 1):

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
OPTION?	7	Calibrate.
LAT dd.mmss?	36.4736 [ENTER]	36°47'36"
LONG ddd.mmss?	121.4658 [ENTER]	121°45'58"
ITD FOR 9940W?	16308 [ENTER]	
ITD FOR 9940Y?	42800 [ENTER]	

The station baselines have now been modified to achieve calibration. Now, reenter 16038 and 42800 into the fixing routine to test the calibration. Calibration does not modify the permanent station data stored in the Model 100. The calibration remains effective until the GRI's are reloaded by Option 8. NOTE: The affect of calibration on the accuracy of fixes far removed from the benchmark has not been studied. The user should use the calibration option with caution.

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
OPTION?	1	Compute a fix.
ITD FOR 9940W?	16308 [ENTER]	
ITD FOR 9940Y?	42800 [ENTER]	
LAT = 36°47'35"	[ENTER]	Lat of fix.
LONG = 121°46'59"	[ENTER]	Long of fix.

The small discrepancy between this fix and the benchmark is due to assumptions in the fixing algorithm. If higher precision is required, the ASF Correction factor may be used (see Sample Problem 5). Note that you may need to use the Alternate Solution Option 2 if the fix obtained above is near 38°52'57"N and 116°51'11'W.

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
OPTION?		Repeat with new option or press A to quit.

TRS-80 MODEL 100 SAMPLE PROBLEM 5

Suppose you are receiving an ITD of 12153.31 microseconds from 9960W and 44451.83 microseconds from 9960Y. These ITD's would tell you that your location is 44°15'05"N and 67°25'23"W. Entering the ASF Correction Tables [Ref. 5,6] with these readings, the ASF Correction for GRI 9960W at 44°15'N and 67°25'W is 1.5 microseconds. Similiarly, the ASF Correction for GRI 9960Y at these coordinates is 2.7 microseconds. Enter these corrections into your Model 100 and recompute your position. (Load the GRI's 9960W and 9960Y using Option 8).

DISPLAY CONTENTS	USER RESPONSE	COMMENTS
OPTION?	9	ASF Correction.
ASF FOR 9960W?	1.5 [ENTER]	
ASF FOR 9960Y?	2.7 [ENTER]	
OPTION?	1	Compute a fix.
ITD FOR 9960W?	12153.31 [ENTER]	
ITD FOR 9940Y?	44451.83 [ENTER]	
LAT = 44°15'26"	[ENTER]	
LONG = 67°26'26"	[ENTER]	
OPTION?		Repeat with new option or press A to quit.

These ASF Corrections have been entered into the computer. The range of their validity must be checked with the ASF Correction tables and reentered if they change. NOTE: If you are using the ASF Correction Tables and if you wish to calibrate to a benchmark position, you should first enter the ASF Corrections for your benchmark and then use the calibration Option 7 (see Sample Problem 4).

```
10 REM LORAN-C ROUTINE. REV 07-15-83. 1530 HOURS
20 N9=15:REM N9 = NO. OF MASTER STATIONS
30 C0=1/298.26:A0=-1:PI=4.*ATN(1):TP=PI+PI:RD=PI/180:G$(1)
=""":GOTO120
32 FORC=1TO9:C$=INKEY$:NEXTC
33 PRINT:PRINT"Press any key to continue."
34 C$=INKEY$:IFC$=""GOTO34
35 RETURN
40 X=INT(M0*X+.5)/M0:RETURN
50 P=129.04398/T-.40758+.645765438E-3*T:RETURN
60 P=2.7412979/T-.32774624-3*T:RETURN
70 C$=INKEY$:IFC$=""GOTO70
80 C=ASC(C$):C$=CHR$(C+32*(C>90))
90 FORC=1TOLEN(C0$):IFC$=MID$(C0$,C,1)THENRETURN
100 NEXTC:GOTO70
120 CLS:PRINT"1-LORAN FIX        6-TWO PT HEAD & DIST"
130 PRINT"2-ALT. SOLUTION    7-CALIBRATE"
140 PRINT"3-DEST LAT/LON     8-NEW STA. IDs "
150 PRINT"4-HEAD & DIST      9-ASF Correction"
160 PRINT"5-PREDICT ITDs     A-STOP
170 PRINT:PRINT"OPTION?":C0$="123456789A":GOSUB70
180
CLS:ONCGOSUB910,950,1010,1040,1090,990,1200,190,1320,530:GOTO120
185 IFG1$<>""THENRETURN
190 F0=1:N=1:CLS:INPUT"1st GRI";I$
200 GOSUB380:GOSUB390:IFF0=2GOTO190
210 F0=1:N=2:INPUT"2nd GRI";I$:GOSUB380
220 IFA$=I9$THENGOSUB470:IFF0=1GOTO250
240 GOSUB390:IFF0=2GOTO210
250 F1=1:F2=1:IFG1$=G2$GOTO300
260 IFP(1,1)=P(1,2)ANDL(1,1)+L(1,2)GOTO310
270 F2=-1:IFP(1,1)=P(2,2)ANDL(1,1)+L(2,2)GOTO310
280 F1=-1:IFP(2,1)=P(2,2)ANDL(2,1)+L(2,2)GOTO310
290 F2=2:IFP(2,1)=P(1,2)ANDL(2,1)+L(1,2)GOTO310
300 PRINT"ERROR: NO TRIPLET.":GOSUB32:GOTO190
310 PRINT:PRINT"Working":FORI=1TO2:P1=P(1,I):L1=L(1,I):P2=P(2,I)
:L2=L(2,I)
320 GOSUB330:NEXTI:G(1)=0:G(2)=0:RETURN
330 GOSUB650:B(I)=S0:Z(1,I)=Z1:Z(2,I)=Z2
340 T=21282.3593*S0
350 IFT>=537THENGOSUB50
360 IFT<537THENGOSUB60
370 T(I)=T+P:RETURN
380 L=LEN(I$):A$=LEFT$(I$,L-1):B$=RIGHT$(I$,1):B=ASC(B$):B$=CHR$(
B+32*(B>90)):RETURN
390 N8=1:RESTORE
400 READI9$,N0,P0,L0
410 FORI=1TON0:READW$(I),D9(I),P1(I),L1(I):NEXTI
420 IFI9$<>A$GOTO450
430 GOSUB470:IFF0=2GOTO460
440 RETURN
```

```
450 N8=N8+1:IFN8<=N9GOTO400
460 PRINTI$;" IS NOT CATALOGED":F0=2:GOSUB32:RETURN
470 FORI=1TON0:IFW$(I)=B$GOTO490
480 NEXTI:F0=2:RETURN
490 IFN=1THENG1$=I$:G$(1)=I$
500 IFN=2THENG2$=I$:G$(2)=I$
510 D(N)=D9(I):X=P0:GOSUB1370:P(1,N)=X:X=L0:GOSUB1360:L(1,N)=V*RD
520 X=P1(I):GOSUB1370:P(2,N)=X:X=L1(I):GOSUB1360:L(2,N)=V*
RD:RETURN
530 END
540 REM DIRECT SOLUTION
550 Z8=SIN(Z1):Z9=COS(Z1):P8=SIN(P1):P9=COS(P1):M=-Z8*P9:C1=C0*
M:C2=C0*(1-M*M)/4
560 D=(1-C2)*(1-C2-C1*M):P=C2*(1+C1*M/2)/D:N=P9*Z9
570 YY=N:XX=P8:GOSUB1260:S1=AN:D0=S0/D:U=2*(S1-D0):W=1-2*P*COS(U)
:V=COS(U+D0)
580 X=C2*C2*SIN(D0)*COS(D0*(2*V*V-1)):Y=2*P*V*W*SIN(D0)
590 S2=D0+X-Y:S8=SIN(S2):S9=COS(S2):K=SQR(M*M+(N*S9-P8*S8)^2)
600 P2=ATN((P8*S9+N*S8)/K)
610 YY=-S8*Z8:XX=P9*S9-P8*S8*Z9:GOSUB1260:S3=AN
620 H=C1*(1-C2)*S2-C1*C2*S8*COS(S1+S1-S2):L2=L1+S3-H
630 YY=-M:XX=-(N*S9-P8*S8):GOSUB1260:Z2=AN:RETURN
640 REM REVERSE SOLN
650 L3=L2-L1:P3=(P2-P1)/2:P4=(P1+P2)/2
660 P6=SIN(P3):P7=COS(P3):P8=SIN(P4):P9=COS(P4)
670 H=P7*P7-P8*P8:L=P6*P6+H*SIN(L3/2)^2:XX=SQR(L):GOSUB1340:D0=2*
AN
680 U=2*P8*P8*P7*P7/(1-L):V=2*P6*P6*P9*P9/L:X=U+V:Y=U-V:T=D0/SIN(
D0):D=4*T*T
690 E=2*COS(D0):A=D*E:C=T-(A-E)/2:N1=X*(A+C*X):B=D+D:N2=Y*(B+E*Y)
:N3=D*X*Y
700 D2=C0*C0*(N1-N2+N3)/64:D1=C0*(T*X-Y)/4:S0=(T-D1+D2)*SIN(D0)
710 M=32*T-(20*T-A)*X-(B+4)*Y
720 F=Y+Y-E*(4-X):G=C0*(T/2+C0*M/64):Q=-F*G*TAN(L3)/4
730 L4=(L3+Q)/2:L8=SIN(L4):L9=COS(L4)
740 YY=P6*L9:XX=P9*L8:GOSUB1260:T1=AN:YY=-P7*L9:XX=P8*
L8:GOSUB1260:T2=AN
750 M0=TP:X=T1+T2:GOSUB1250:Z1=X:X=T1-T2:GOSUB1250:Z2=X:RETURN
760 REM FIXING ROUTINE
770 A1=F1*SIN(A(1)):B1=COS(A(1))-COS(B(1)):C1=SIN(B(1))
780 A2=F2*SIN(A(2)):B2=COS(A(2))-COS(B(2)):C2=SIN(B(2))
790 E1=Z(1,1):IFF1=-1THENE1=Z(2,1)
800 E2=Z(1,2):IFF2=-1THENE2=Z(2,2)
810 C=B1*C2*COS(E2)-B2*C1*COS(E1):S=B1*C2*SIN(E2)-B2*C1*SIN(E1)
820 K=B2*A1-B1*A2:R=SQR(C*C+S*S):YY=S:XX=C:GOSUB1260:G=AN
830 XX=K/R:GOSUB1350:Z=G+A0*AN:YY=B2:XX=C2*COS(Z-E2)+
A2:GOSUB1260:S0=AN
840 IFF2=1THENP1=P(1,2):L1=L(1,2)
850 IFF2=-1THENP1=P(2,2):L1=L(2,2)
860 Z1=Z:GOSUB550:P0=P2:L0=L2:P=ATN(TAN(P0)/(1-C0))
```

```
870 P=P/RD:X=L0/RD:M0=360:GOSUB1250:L=X:IFL>180THENL=L-360
880 X=P:GOSUB1280:P$=C$:X=L:GOSUB1280
890 PRINT:PRINT"LAT  = ";P$:PRINT"LONG = ";C$:RETURN
900 REM OPT 1
910 GOSUB185:CLS:FORI=1TO2
920 PRINT"ITD FOR ";G$(I);:INPUTA:A=A+G(I)-D(I)-T(I):IFABS(A)<T(I)
GOTO940
930 PRINT"ITD NOT VALID FOR ";G$(I):GOSUB32:GOTO920
940 A(I)=A/21295.8736:NEXTI:GOSUB770:GOSUB32:RETURN
945 REM OPT 2
950 IFA0=1THENA0=-1:GOTO970
960 A0=1
970 GOSUB770:GOSUB32:RETURN
980 REM OPT 6
990 CLS:INPUT"ORIGIN LAT   dd.mmss";P:INPUT"ORIGIN LONG
ddd.mmss";L
1000 X=P:GOSUB1370:P0=X:X=L:GOSUB1360:L0=V*
RD:GOSUB1010:GOSUB1040:RETURN
1010 CLS:INPUT"DEST LAT   dd.mmss";P:INPUT"DEST LONG ddd.mmss";L
1020 X=P:GOSUB1370:P5=X:X=L:GOSUB1360:L5=V*RD:RETURN
1030 REM OPT 4
1040 P1=P0:L1=L0:P2=P5:L2=L5:GOSUB650
1050 M0=360:X=Z1/RD:GOSUB1250:GOSUB1280
1060 CLS:PRINT"HEADING = ";C$:M0=100:X=3443.917*
S0:GOSUB40:PRINT"DISTANCE = ";X;" n. mi."
1070 GOSUB32:RETURN
1080 REM OPT 5
1090 GOSUB185:GOSUB1170:PRINT:FORK=1TO2:I9=T(K)+D(K)
1100 P2=P(2,K):L2=L(2,K):GOSUB650:I=3:GOSUB340:I9=I9+T(3)
1110 P2=P(1,K):L2=L(1,K):GOSUB650:I=3:GOSUB340:I9=I9-T(3)
1120 M0=100:X=I9:GOSUB40
1130 PRINT"ITD FOR ";G$(K);" = ";X:NEXTK
1140 PRINT:PRINT"New lat/long or Return to menu?":C0$="NR":GOSUB70

1150 IFC=1GOTO1090
1160 RETURN
1170 CLS:INPUT"LAT   dd.mmss";P1:INPUT"LONG ddd.mmss";L1
1180 X=P1:GOSUB1370:P1=X:X=L1:GOSUB1360:L1=V*RD:RETURN
1190 REM OPT 7
1200 GOSUB185:GOSUB1170:FORK=1TO2:I$=G1$:IFK=2THENI$=G2$
1210 CLS:PRINT"ITD FOR ";I$;:INPUT I9:I9=I9-D(K)
1220 P2=P(2,K):L2=L(2,K):GOSUB650:I=3:GOSUB340:I9=I9-T(3)
1230 P2=P(1,K):L2=L(1,K):GOSUB650:I=3:GOSUB340:T(K)=I9+T(3)+G(K)
1240 NEXTK:RETURN
1250 X=X-M0*INT(X/M0):REM MOD FCTN
1260 AN=ATN(YY/(XX-1E-9*(XX=0)))-PI*(XX<0):RETURN:REM QATN
1270 X=ATN((1-C0)*TAN(X)):RETURN
1280 C$=" ":IFX<0THENC$="-":X=-X
1290 X=X+1/7200:X0=INT(X):C$=C$+STR$(X0)+" "
1300 X=60*(X-X0):X0=INT(X):X$=STR$(100+X0):C$=C$+RIGHT$(X$,2)+" "
```

```
1310 X=60*(X-X0):X0=INT(X):X$=STR$(100+X0):C$=C$+RIGHT$(X$,2)+"
":RETURN
1320 GOSUB1185:CLS:PRINT"ASF FOR ";G$(1);:INPUTG(1)
1330 PRINT"ASF FOR ";G$(2);:INPUTG(2):RETURN
1340 ZZ=SQR(1-XX*XX):AN=ATN(XX/(ZZ-1E-9*(ZZ=0))):RETURN:REM ASIN
1350 AN=ATN(SQR(1-XX*XX)/(XX-1E-9*(XX=0)))-PI*(XX<0):RETURN:REM
ACOS
1360 S=SGN(X):X=ABS(X): H=INT(X):M0=1:GOSUB1250:V=X*
100:X=V:GOSUB1250
1365 V=S*((100*X/60+INT(V))/60+H):RETURN
1370 GOSUB1360:X=V*RD:GOSUB1270:RETURN
5000 DATA
"4990",2,16.444395,169.30312,"X",11000,20.144916,155.53097
5010 DATA "Y",29000,28.234177,178.17302
5020 DATA
"5930",2,46.4827199,67.5537713,"X",11000,41.151193,69.583909
5030 DATA "Y",25000,46.46463218,53.102816
5040 DATA "5970",3,36.1105797,-129.2027279,"W",11000,42.4437104,-
143.4309245
5050 DATA "X",31000,35.0223871,-126.322674,"Z",42000,263624975,-
128.0856445
5060 DATA
"5990",3,51.575878,122.220224,"X",11000,55.2620851,131.1519648
5070 DATA
"Y",27000,47.034799,119.443953,"Z",41000,50.3629731,127.2129043
5080 DATA
"7930",3,59.591727,45.102747,"W",11000,64.542658,23.552175
5090 DATA
"X",21000,62.175964,7.0426538,"Z",43000,46.463218,53.102816
5100 DATA "*7930",3,24.1707888,-153.5853232,"X",11000,42.4437104,-
143.4309245
5110 DATA "Y",30000,26.3624975,-128.0856445,"Z",49000,9.3245789,-
138.095497
5120 DATA
"7960",2,63.1942814,142.48319,"X",11000,57.262021,152.2211225
5130 DATA "Y",26000,55.2620851,131.1519648
5140 DATA "7970",4,62.175964,7.0426538,"W",26000,54.4829872,-
8.1736312
5150 DATA "X",11000,68.380615,-
14.2747,"Y",46000,64.542658,23.552175
5160 DATA "Z",60000,70.545261,8.435869
5170 DATA
"7980",4,30.593874,85.1009305,"W",11000,30.4333018,90.49436
5180 DATA
"X",23000,26.3155006,97.5000093,"Y",43000,27.0158393,80.0653429
5190 DATA "Z",59000,34.0346081,77.5446654
5200 DATA "7990",3,38.5220587,-16.4306159,"X",11000,35.3120787,-
12.3130245
```

```
5210 DATA "Y",29000,40.582095,-27.520152,"Z",47000,42.0336515,-
3.1215512
5220 DATA
"8970",3,39.510754,87.291214,"W",11000,30.593874,85.1009305
5230 DATA
"X",28000,42.4250603,76.4933862,"Y",44000,48.3649844,94.3318469
5240 DATA
"9940",3,39.3306621,118.495637,"W",11000,47.034799,119.443953
5250 DATA
"X",27000,38.465699,122.2944529,"Y",40000,35.191818,114.4817435
5270 DATA
"9960",4,42.4250603,76.4933862,"W",11000,46.4827199,67.5537713
5280 DATA
"X",25000,41.151193,69.583909,"Y",39000,34.0346081,77.5446654
5290 DATA "Z",54000,39.510754,87.291214
5300 DATA "9970",4,24.4803597,-141.1930303,"W",11000,24.1707888,-
153.5853232
5310 DATA "X",30000,42.4437104,-143.4309245,"Y",55000,26.3624975,-
128.0856445
5320 DATA "Z",75000,9.3245789,-138.095497
5330 DATA "9990",3,57.091265,170.1506789,"X",11000,52.494404,-
173.1048974
5340 DATA
"Y",29000,65.1440306,166.531255,"Z",43000,57.262021,152.2211225
```

V. MEMORY REQUIREMENTS

	HP-75C	PC-1500 (TRS-80 PC-2)	TRS-80 MODEL 100
Memory (bytes) for:			
Program	7747	7189	7220
Variables	4920	?	4786
TOTAL	12667	?	12006

VI. REFERENCES

1. J. A. Pierce, A. A. McKenzie and R. H. Woodward, editors, LORAN, M.I.T. Radiation Laboratory Series, McGraw-Hill Book Company, Inc., 1948.

2. G. Hefley, The Development of Loran-C Navigation and Timing, National Bureau of Standards Monograph 129, U.S. Department of Commerce, U.S. Government Printing Office, Washington, D.C. 20402, October 1972.

3. R. H. Shudde, "Position Determination with LORAN-C Triplets and the Hewlett-Packard HP-41CV Programmable Calculator", Technical Report NPS55-82-022, September 1982, Naval Postgraduate School, Monterey, CA 93940.

4. J. J. Speight, "DMAHTC Support to National Ocean Survey Loran-C Charting", NAVIGATION: Journal of The Institute of Navigation, Vol. 29, No. 1, Pg. 22, 1982.

5. The following tables of ASF Corrections are available from the Defense Mapping Agency Office of Distribution Services, Washington, D.C. 20315:

DMA Stock Number	Title
LCPUB2211100C	East Coast Canada (Pairs 5930-X,Y)
LCPUB2211200C	Northeast USA (Pairs 9960-W,X,Y,Z)
LCPUB2211300C	Great Lakes (Pairs 8970-X,Y,Z)
LCPUB2211400C	Southeast USA (Pairs 7980-W,X,Y,Z)
LCPUB2212100C	West Coast of USA (Pairs 9940-W,X,Y)
LCPUB2212200C	West Coast Canada (Pairs 5990-X,Y,Z)
LCPUB2212300C	Gulf of Alaska (Pairs 7960-X,Y)
LCPUB2212400C	North Pacific (Pairs 9990-X,Y,Z)

Appendix: LORAN-C STATION DATA

The following list contains the pertinent parameters for each Loran-C station pair. This list was compiled from the data in Reference 4. Each column contains the following information:

1. The Loran-C station pair designator.
2. The coding delay.
3. The master station latitude.
4. The master station longitude.
5. The slave station latitude.
6. The slave station longitude.

In this list, positive longitudes are West, negative longitudes are East, positive latitudes are North and negative latitudes are South. In columns 3 through 6 the latitudes and longitudes appear to be in decimal form, but the actual format is DDD.MMSSFFF where

DDD designates degrees,
MM designates minutes,
SS designates seconds, and
FFF designates thousandths of seconds.

LORAN-C STATIONS

GRI	CD	MS LAT	MS LON	SS LAT	SS LON
4990X	11000	16.4443950	169.3031200	20.1449160	155.5309700
4990Y	29000	16.4443950	169.3031200	28.2341770	178.1730200
5930X	11000	46.4827199	067.5537713	41.1511930	069.5839090
5930Y	25000	46.4827199	067.5537713	46.4632180	053.1028160
5970W	11000	36.1105797	-129.2027279	42.4437104	-143.4309245
5970X	31000	36.1105797	-129.2027279	35.0223871	-126.3226741
5970Z	42000	36.1105797	-129.2027279	26.3624975	-128.0856445
5990X	11000	51.5758780	122.2202240	55.2620851	131.1519648
5990Y	27000	51.5758780	122.2202240	47.0347990	119.4439530
5990Z	41000	51.5758780	122.2202240	50.3629731	127.2129043
7930W	11000	59.5917270	045.1027470	64.5426580	023.5521750
7930X	21000	59.5917270	045.1027470	62.1759640	007.0426538
7930Z	43000	59.5917270	045.1027470	46.4632180	053.1028160
*7930X	11000	24.1707888	-153.5853232	42.4437104	-143.4309245
*7930Y	30000	24.1707888	-153.5853232	26.3624975	-128.0856445
*7930Z	49000	24.1707888	-153.5853232	09.3245789	-138.0954970
7960X	11000	63.1942814	142.4831900	57.2620210	152.2211225
7960Y	26000	63.1942814	142.4831900	55.2620851	131.1519648
7970W	26000	62.1759640	+007.0426538	54.4829872	-008.1736312
7970X	11000	62.1759640	+007.0426538	68.3806150	-014.2747000
7970Y	46000	62.1759640	+007.0426538	64.5426580	+023.5521750
7970Z	60000	62.1759640	+007.0426538	70.5452610	+008.4358690
7980W	11000	30.5938740	085.1009305	30.4333018	090.4943600
7980X	23000	30.5938740	085.1009305	26.3155006	097.5000093
7980Y	43000	30.5938740	085.1009305	27.0158393	080.0653429
7980Z	59000	30.5938740	085.1009305	34.0346081	077.5446654
7990X	11000	38.5220587	-016.4306159	35.3120787	-012.3130245
7990Y	29000	38.5220587	-016.4306159	40.5820950	-027.5201520
7990Z	47000	38.5220587	-016.4306159	42.0336515	-003.1215512
8970W	11000	39.5107540	087.2912140	30.5938740	085.1009305
8970X	28000	39.5107540	087.2912140	42.4250603	076.4933862
8970Y	44000	39.5107540	087.2912140	48.3649844	094.3318469
9940W	11000	39.3306621	118.4956370	47.0347990	119.4439530
9940X	27000	39.3306621	118.4956370	38.4656990	122.2944529
9940Y	40000	39.3306621	118.4956370	35.1918180	114.4817435
9960W	11000	42.4250603	076.4933862	46.4827199	067.5537713
9960X	25000	42.4250603	076.4933862	41.1511930	069.5839090
9960Y	39000	42.4250603	076.4933862	34.0346081	077.5446654
9960Z	54000	42.4250603	076.4933862	39.5107540	087.2912140
9970W	11000	24.4803597	-141.1930303	24.1707888	-153.5853232
9970X	30000	24.4803597	-141.1930303	42.4437104	-143.4309245
9970Y	55000	24.4803597	-141.1930303	26.3624975	-128.0856445
9970Z	75000	24.4803597	-141.1930303	09.3245789	-138.0954970
9990X	11000	57.0912265	+170.1506789	52.4944040	-173.1048974
9990Y	29000	57.0912265	+170.1506789	65.1440306	+166.5312550
9990Z	43000	57.0912265	+170.1506789	57.2620210	+152.2211225

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